SPECIAL EROSION CONTROL STUDY

SOUTH SHORE OF MOUTH OF MERRIMACK RIVER

VICINITY OF U.S. COAST GUARD STATION

PLUM ISLAND, MASSACHUSETTS

DEPARTMENT OF THE ARMY

NEW ENGLAND DIVISION, CORPS OF ENGINEERS

WALTHAM, MASSACHUSETTS 02154

JUNE 1969

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SOUTH SHORE OF MOUTH OF MERRIMACK RIVER
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VICINITY OF U.S. COAST GUARD STATION

PLUM ISLAND, MASSACHUSETTS

1. General. This is a special study on a serious erosion problem occurring during the early months of 1969 to U. S. Coast Guard and other Government property at Plum Island, Massachusetts. The problem area has been visited by the Division Engineer and his coastal engineering personnel. Meetings have been held with U. S. Coast Guard officials to consider what type of corrective measures, if any, should be undertaken. Continued erosion is going to force the U. S. Coast Guard to make an imminent decision on continuing here, possibly with new construction inland, or abandonment of the station.

2. Location and Description. The problem area extends along the south shore of the entrance to Newburyport Harbor at the mouth of the Merrimack River. This area forms a part of the northern extremity of Plum Island in the City of Newburyport, Massachusetts, located about 50 miles north of Boston, Massachusetts, and 20 miles south of Portsmouth, New Hampshire (see PLATE I). The developed Coast Guard complex consists of a large paved area containing several structures, with the old south jetty actually extending inland under the development. The entire problem area consists of sandbanks or dunes susceptible to erosion by wave action and storm water runoff.

3. The Problem. The erosion along the south shore of the harbor entrance (see PHOTO 2) resulted from a series of three storms occurring between 9 and 27 February 1969. One storm lasted several days. A description of the storms is given in TABLE I. The storms occurred in a series, accompanied by strong northeast winds (40 to 50 miles per hour, fastest mile) with moderate wave action, and extended through a number of high tides (probably at least 18). The storms occurred during a period of neap or near neap tides. Otherwise, the storm-caused erosion could have been more severe. Based

TABLE I - TIDE AND STORM CONDITIONS DURING SERIES OF DAMAGING STORMS

FEBRUARY 1969

DATE[1]	STORM PERIODS[2]	WEATHER	WIND DIRECTION	WIND VELOCITY MPH (FASTEST MI.)	PREDICTED TIDE EL. (FT. M. L. W.)		EST. TIDE LEVEL (FT. M. L. W.)	
9 Feb.	First	Snow Storm	Northeast	52	9.1	8.0	11.4	10.3
10 Feb.	"	" "	"	52	9.1	7.7	11.4	10.0
19 Feb.	Second	Rain & Slight Snow	"	27	9.7	9.8	12.0	12.0
20 Feb.	"	" " " "	"	27	9.5	9.2	11.8	11.5
21 Feb.	"	" " " "	"	27	9.3	8.5	11.6	10.8
24 Feb.	Third	Snow Storm	"	32 - 45	8.2	6.8	10.5	9.1
25 Feb.	"	" "	"	32 - 45	8.0	6.7	10.3	9.0
26 Feb.	"	" "	"	32 - 45	7.9	6.8	10.2	9.1
27 Feb.	"		"	32 - 45	8.0	7.0	10.3	9.3

[1] Perigee and apogee tides on 14 and 25 February, respectively.

[2] Three near consecutive storms with estimated tide levels at times approaching design tide conditions.

on oral reports and comparative surveys made for the Plum Island Beach Erosion Study (1968), and an after-storm survey (1969), the mean high waterline receded from at least 150 feet at the Coast Guard Station to 450 feet at the inner bar, located about 2, 000 feet to the west. Also, a lowering of the backshore of up to 10 feet, and the foreshore and nearshore to the navigation channel by an average amount of 2 feet, occurred (see PHOTO 1 and PLATE 2). It is conservatively estimated that about 1 million cubic yards of sand was eroded (about 800, 000 cubic yards from the backshore area), with most of it deposited on the outer bar extending along the ocean shorefront. The material deposited offshore and in the outer channel could be readily seen in the new, exposed shoals located along the Plum Island shorefront. Field investigations now indicate that storm waves overtopped the dunes or backshore, estimated to be at least 18. 0 feet above mean low water, and carried debris and sand as far as 200 feet inland. An inner row of dunes within the entrance is now vulnerable to future wave damage from a recurrence of a severe storm. An Air Force Reservation in the vicinity lost about 200 feet of fence, further demonstrating the serious loss experienced during these storms.

4. Coast Guard personnel have stated that the large land losses experienced at the Coast Guard Station appeared to have been caused in part by the uncompleted jetty rehabilitation in progress at the time of the storms. They stated that their observations during the storms indicated alongshore currents at Plum Island, combined with the waves directed from the northeast, caused rapid loss of material. Field investigations indicate that the relative smoothness of the new jetty cross-section, combined with the relatively low-level opening resulting between the inner end of the uncompleted jetty and the dunes fronting the seaward shore of the station, very likely did play such a role. The opening acted as a spillway, probably increasing the velocity of runup, overtopping through it, thus causing flanking of the structure and expediting alongshore losses along the immediate river bank shorefront. PHOTO 2 shows the jetty construction and the opening at the inner end.

5. Shoreline History. A study of the general history of the Plum Island shorefront has been made based on shoreline change maps extending through a period dating back to 1827. In 1827, the Plum Island basin was not in existence and the mouth of the Merrimack River was centered about 2, 000 feet to the south, sweeping across

a 2,000-foot wide section of land which is now developed. Sometime between 1827 and 1851 the inner basin was formed and a trailing spit or bar curved northwestward. The mouth of the river widened out and most of the presently developed area north of the Plum Island Turnpike was under water. By 1881-1883, when construction of the north and south jetties was first initiated, the mouth of the river had migrated to the north to about its present location.

6. The construction of the jetties resulted in stabilization of the mouth of the river and by 1890 the mean high water shoreline had extended out as much as 400 feet on the north side of the south jetty and 600 feet seaward on the south side. The substantial initial buildup likely resulted from rapid movement of sand along the trailing spit to the north during southeast storms and/or by easterly waves refracted to the north over the outer bar. Much of the sand thus carried was trapped at the jetty. However, some of the sand overtopped the jetty or moved through the old, moderately permeable jetty structure, with a large amount passing around the end of the jetty, which built up along the north side of the structure. The mean high water shoreline has both receded and accreted along the northern side of the jetty structure but has never approached the original condition of exposure for the entire length, which condition prevailed at the time of its construction in 1881. Also, by 1890 the inner migrating bar had taken shape and had continued to build into the river until 1931 when it protruded some 1,000 feet further into the river. This bar formation resulted in a change in direction of the channel toward the north jetty directing the ebb current northward and resulting in some scouring and deepening near the inner end of the north jetty structure (see PLATE 3).

7. Effect of Residential Development. The large scale development along the northern sector of Plum Island has seriously changed the environment. Prior to the construction of paved streets and cottages, the natural structure of dunes, and beach grass growth, helped to stabilize and even, through wind movement combined with tidal processes, favored a northerly accretion at times. Under the present conditions, however, no appreciable buildup of a protective beach along the river shorefront above serious tidal flood elevations can be expected.

8. Rehabilitation of Jetties. The jetties are presently being restored to their original size but with the addition of some stone on the inner ends, including measures to prevent sand moving through and overtopping the jetties within the surf zone and the exposed backshore area of the south jetty. The inner end of the jetty through a portion of the backshore area is being raised to 19.0 feet above mean low water, which is about 3 feet above the suggested elevation in the beach erosion study, or about 3 feet above the existing level of the beach where it terminates, leaving an opening about 200 feet wide between its termination and the dune fronting the Coast Guard Station.

9. Effects of Jetty Rehabilitation. The restoration of the jetties to their original condition with the outer arms at 12.0 feet above mean low water will cause some reduction in wave heights below those experienced at this time, particularly those waves approaching from the east northeast that sweep over the outer arm of the north jetty, whose top elevation presently averages only 9.0 feet above mean low water. The raising and tightening of the south jetty should act to produce some additional widening along the south shore during periods when a northerly littoral drift condition prevails; however, the jetty should be tied back into high ground to prevent flanking of the structure from wave runup and overtopping. There should be a moderate decrease of material moving in to nourish the inner entrance south shore area by stopping the flow of material from the south which formerly overtopped and moved through the jetty within the surf zone and backshore area. This, of course, is desirable for both the navigation improvement by reducing shoaling of the channel and for the beach erosion control improvement along the oceanfront problem area to the south, with some accretion of sand occurring south of the jetty and some widening of the beach experienced along the problem area.

10. Design Criteria. The design of rockfill structures was predicated on the WES formula and criteria set forth in TR-4, using the maximum wave height that could be supported at the toe, allowing for about 4 feet of erosion, but also considering the significant wave that could be occurring based on hindcast and refraction analysis.

11. Design Tide. The design tide selected is about 3.7 feet above mean high water (12.0 feet above mean low water) which is considered both practical and in line with the beach erosion control study findings.

12. Wave Height. The significant deep water wave height and direction that will occur is determined through hindcast procedures using the wave criteria in TM-55, "North Atlantic Coast Wave Statistics", by the Beach Erosion Board, now the Coastal Engineering Research Center, and based on the Penobscot station. A study indicated that east northeast and easterly wave approaches, with a wave height of 15 feet and a period of 8 seconds, would produce the frequent storm damaging conditions. Refraction and diffraction of the waves would reduce the waves to about 6 feet within the entrance, vicinity of the Coast Guard Station, but easterly waves entering the opening directly average around 8 feet along the easterly exposed area. The 6-foot wave height is, therefore, used for the design of the structure.

13. Runup. Because of the serious condition at the Coast Guard Station, with erosion leaving only about 45 feet of bank now fronting the river side of the Coast Guard barracks structure (see PHOTOS 2 and 3), runup studies have been made for the design condition for various slopes of rock-faced protection. It has been determined that, to eliminate wave overtopping at the exposed outer sector, revetment should have no slope flatter than 5 horizontal and 1 vertical. Also, level width of at least 70 feet at the existing elevation of the bank, but not less than 20.0 feet above mean low water, should be provided at the station proper.

14. Corrective Measures. Of major importance in consideration of an improvement is the importance of the Coast Guard complex within this area of extensive recreational boating and salt water bathing activities, now estimated by the Coast Guard to cost about $750,000 to replace and relocate inland, under present-day construction standards and cost. Several plans of improvement have been considered for preservation of the point at the Coast Guard Station complex and also from the viewpoint of preservation of land along the south shore and reducing shoaling within the navigation channel. The ordinary methods of erosion control for an area such as this, if on the open ocean front, would be by dune and beach restoration, possibly combined with groin structures for compartmenting the

the beach fill. This type of improvement, however, experiences substantial offshore sand losses and would not be feasible since the purpose is also to reduce shoaling within the navigation channel. A rockfill structure extending alongshore and tying into stable dunes beyond the inner bar, retaining pumped sandfill behind it, although protecting the backshore area and reducing shoaling within the navigation channel, is very expensive, exceeding $1,500,000 in cost. The most practical plan of protection for initial construction for protection of the Coast Guard complex and protecting the jetty from flanking, or costly maintenance work on the old jetty, is as follows:

Provide a protective improvement by extension of the present jetty construction landward with a top elevation at 19.0 feet above mean low water tying into the backshore, and construction of a sandfill rock-protected embankment along 400 feet of river front at the station, furnishing 70 feet of level width at a minimum elevation of 20 feet above mean low water fronting the barracks, thence sloping riverward on a slope of 5 horizontal on 1 vertical, and retained by a rock toe with a top elevation of 10.0 feet above mean low water. This structue would tie into the jetty and blend into a rock revetment which would continue westward an additional 200 feet. See PLATE 4 for the considered plan of improvement, and PHOTO 4 showing western extent of shore to be protected.

15. First Cost. The first cost of the project is based on the current 1969 price level and prices used in the jetty construction now in progress. The first cost of the plan is tabulated below:

First Cost of Plan of Improvement

Item	Est. Quantity	Unit	Unit Cost	Est. Amount
Massive Section				
Armor Stone	1,900	tons	$20.00	$38,000
Core & Bedding Stone	8,200	"	10.00	82,000
Cover Stone	7,000	"	5.00	35,000
Sand Fill	8,500	c. y.	1.50	13,000
Gravel Fill	1,300	"	3.00	4,000
Rock Revetment Section				
Armor Stone	1,500	tons	20.00	30,000
Bedding Stone	1,200	"	10.00	12,000
Gravel	160	c. y.	3.00	500
Jetty Extension	1	job	lump sum	25,000
		SUB TOTAL		$239,500

(Cont'd)

First Cost of Plan of Improvement (Cont'd)

	SUB-TOTAL	$239,500
Contingencies		35,000
	Sub-Total	$274,500
Engineering and Design		16,500
Supervision and Administration		24,000
	TOTAL COST	$315,000

16. Annual Charges. The annual charges are computed using an interest rate of 4-5/8 percent and a useful project life of 50 years. The annual charges would, therefore, be as follows:

Interest on investment (0.04625 x $315,000)	$ 14,300
Amortization (0.00538 x $315,000)	1,700
Maintenance	5,000
TOTAL ANNUAL CHARGES	$ 21,000

17. Benefits. Benefits are based on (1) savings in cost of rebuilding the Coast Guard complex inland, (2) savings in probable reconstruction of the old jetty, (3) savings in reduction of sand deposits in channel from future erosion of the backshore areas extending along about 600 feet of riverfront area, and (4) prevention of land loss along both the riverbank area and for a limited ocean shorefront distance. The estimated benefits are as follows:

Interest on Investment	
Savings of $750,000, construction of Coast Guard complex. (0.04625 x $750,000)	$ 34,800
Amortization (0.00538 x $750,000)	4,000
Interest on estimated savings of at least $300,000 of old jetty reconstruction (0.04625 x $300,000)	13,900
Amortization (0.00538 x $300,000)	1,600
Land loss prevention - ocean shore and river shore	3,000
Reduction in shoaling of channel	5,000
	$ 62,300
BENEFIT-COST RATIO	2.9

18. Discussion. The Coast Guard Station, which is the main beneficiary and the primary reason for the erosion control measure, has been located here since its construction in 1930. The prime function of the station located in this area, in addition to the standard mission of going to the aid of shipping in distress, is to provide security and well-being by expeditious rescue service to an increasing number of recreational small boatsmen, fishermen and salt water bathers within the nearby area. The most economical means of preservation of the Coast Guard complex, within this area, is by in-place protection rather than by moving inland.

19. Conclusions and Recommendations. It is concluded that the Federal interest will be best served by the preservation of Government property, U. S. Coast Guard and U. S. Army Engineers, at the northerly end of Plum Island. The Coast Guard Station serves as a headquarters and a barracks building. Therefore, intangible benefits would result from protection to life by preservation of the point, as well as monetary benefits from direct protection to the Coast Guard complex and the Corps jetty. These benefits would be realized and, in the interest of the serious problem and imminent loss of the Coast Guard complex, immediate construction of an erosion control improvement, by extending the jetty landward, tying into the backshore and revetting along the river in accordance with the plan shown on PLATE 4, is recommended. The cost of construction for this plan is estimated at $315,000 and has a benefit-cost ratio of 2.9 to 1.0.

20. It is also concluded that, in the interest of economy of maintenance of the navigation improvement and preservation of property, extension of the protection at a later date along the backshore may be economically accomplished either by continuing the revetment alongshore to the inner harbor unexposed stable dunes west of the inner bar, or by construction of a protective alongshore rock breakwater structure, retaining pumped sandfill from the inner and outer bars, this structure tying into the considered improvement. It is recommended that this should be accomplished only after observation and continued comparative hydrographic surveys are undertaken for a substantial period of time to evaluate land loss and the amount of sandfill moving from the inner harbor to the channel. Such observation will assure economic justification of the more comprehensive plan.

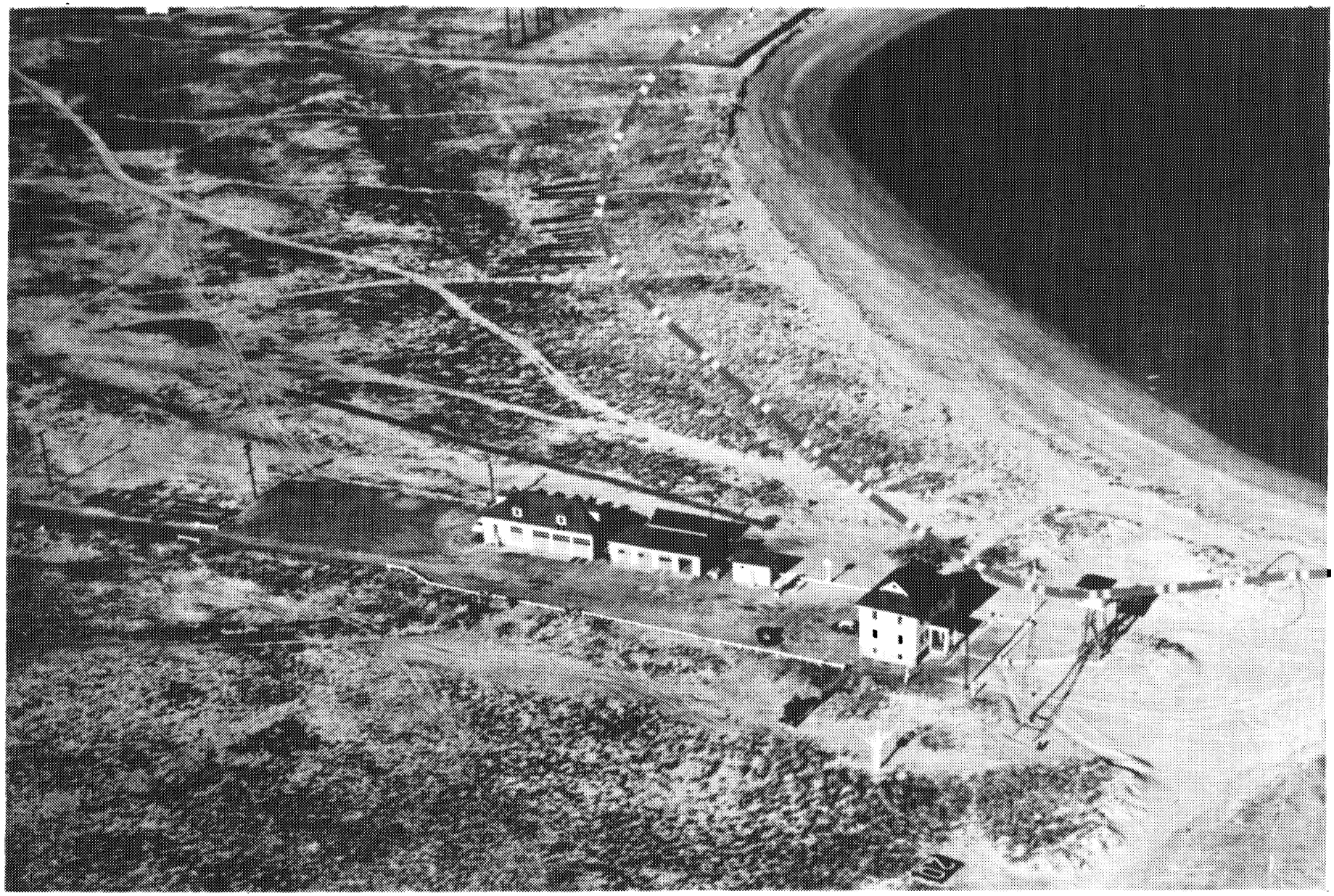

Photo 1. Looking northwest at United States Coast Guard Station, showing bank before erosion and approximate top of bank after erosion

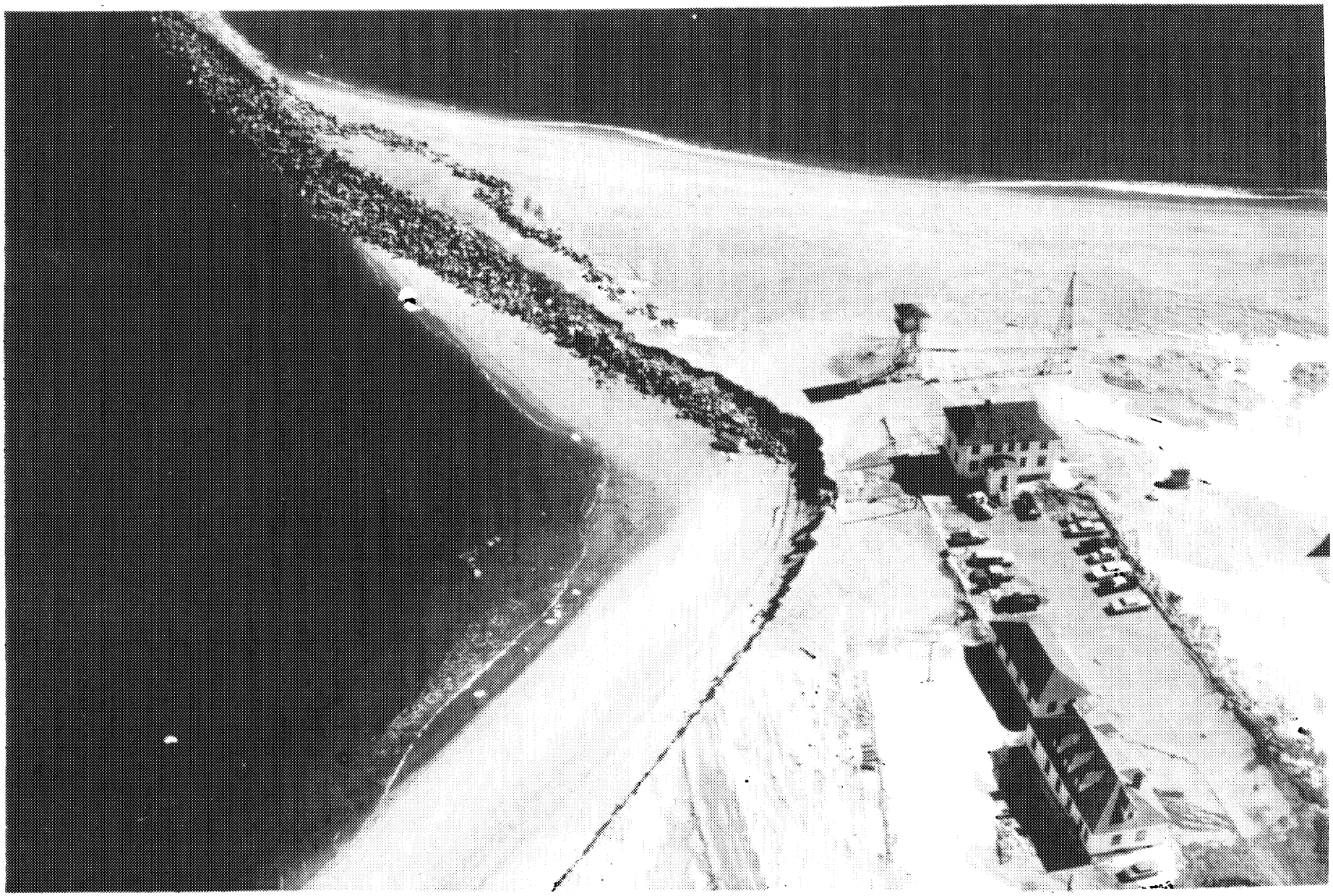

Photo 2. **Looking east during intermediate tide along south jetty and top of dunes after erosion.** Note location of dune line at Coast Guard Station and at opening inner end of jetty that is subjected to storm wave runup and overtopping.

Photo 3. April 1969 Coast Guard Station in the background. Top of bank is now 45 feet from station. Spring tide approaches base of slope. (Note: Since this photo, erosion has continued inland to undermine the fence)

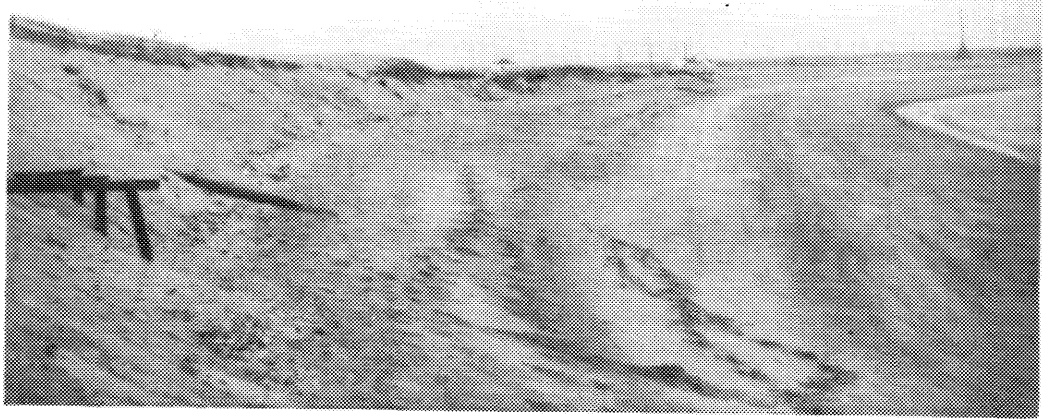

Photo 4. April 1969 Looking west along shoreline during low tide, along eroding bank vicinity of the Coast Guard Station.

CORPS OF ENGINEERS

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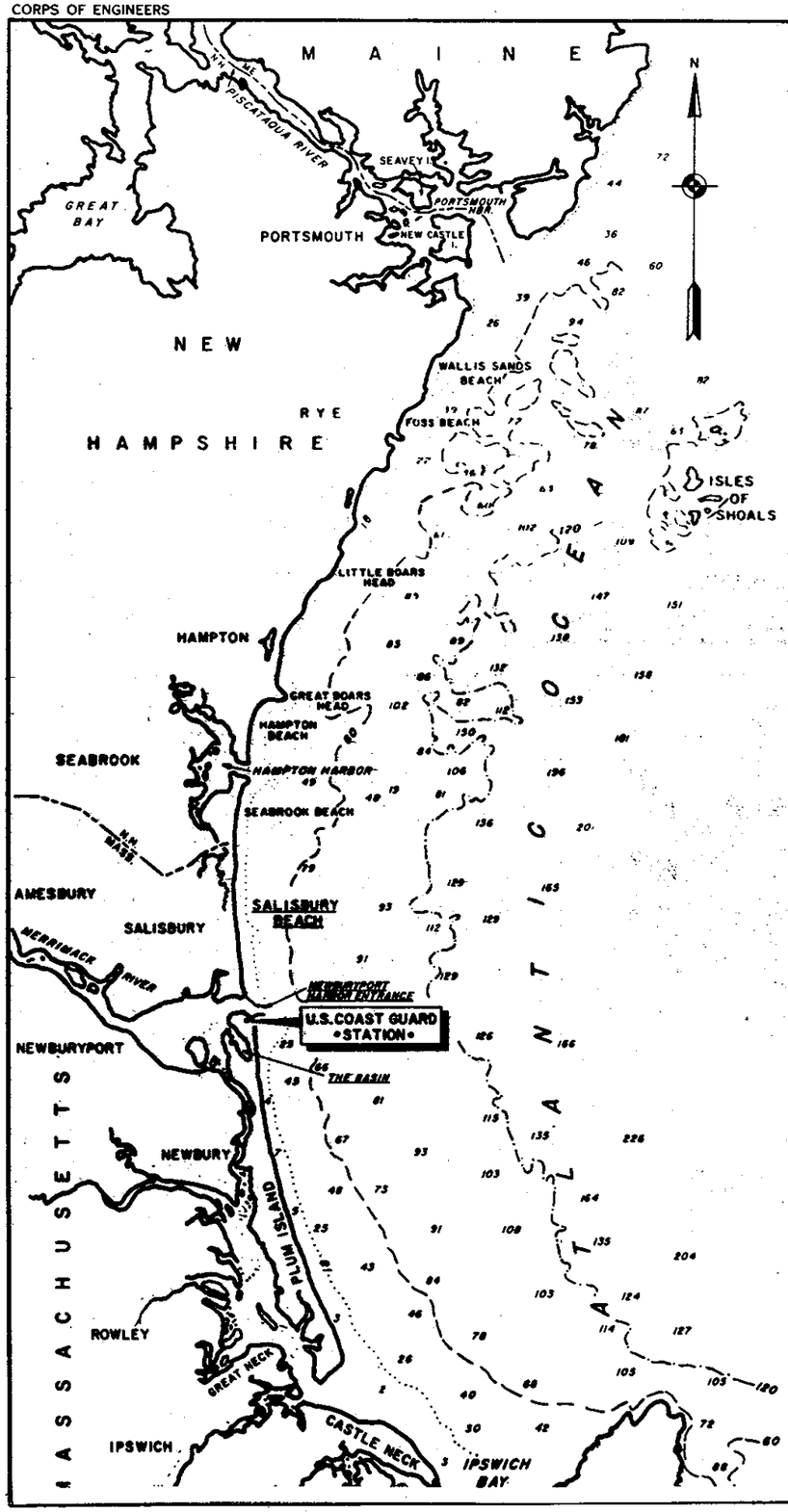
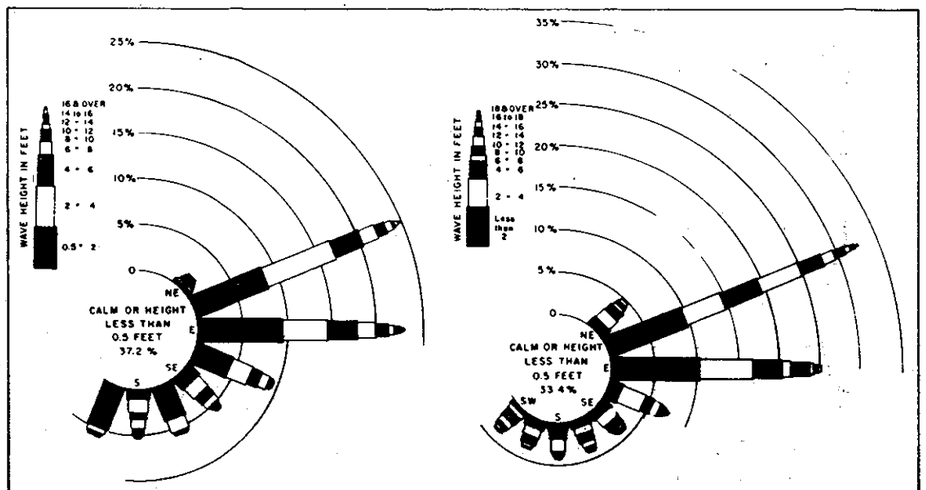


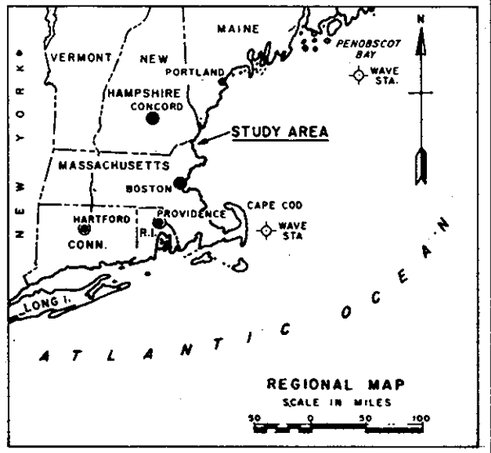


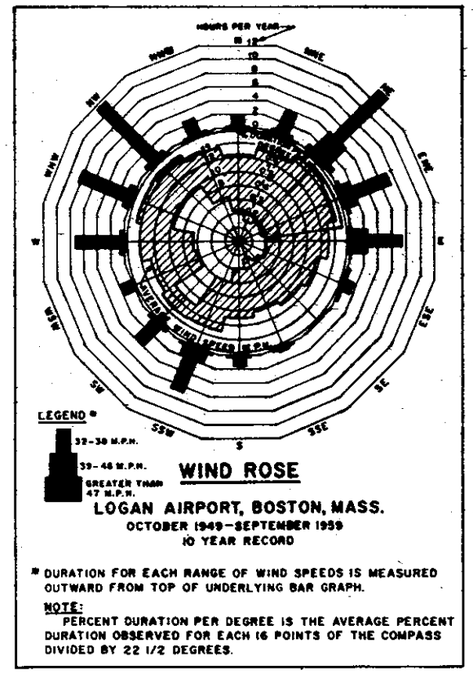
OFF PENOBSCOT BAY, MAINE
(LAT. 43° 50' N, LONG. 68° 00' W)
(SEE REGIONAL MAP)

OFF NAUSET BEACH, CAPE COD, MASS.
(LAT. 41° 50' N, LONG. 69° 30' W)
(SEE REGIONAL MAP)

WAVE DIAGRAMS

COMPOSED OF DATA OBTAINED BY HINDCAST OF 3 YEARS OF WIND RECORDS (1948-1950) SHOWING PERCENT OF TIME WAVES OF DIFFERENT HEIGHT OCCUR FROM EACH DIRECTION. FROM BEACH EROSION BOARD TECHNICAL MEMORANDUM NO. 55.





WIND ROSE

LOGAN AIRPORT, BOSTON, MASS.
OCTOBER 1949-SEPTEMBER 1959
10 YEAR RECORD

* DURATION FOR EACH RANGE OF WIND SPEEDS IS MEASURED OUTWARD FROM TOP OF UNDERLYING BAR GRAPH.

NOTE:
PERCENT DURATION PER DEGREE IS THE AVERAGE PERCENT DURATION OBSERVED FOR EACH 16 POINTS OF THE COMPASS DIVIDED BY 22 1/2 DEGREES.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY	TR. BY	CH. BY
T.C.B.	A.D.C.	C.E.W

SUBMITTED:
PROJECT ENGINEER
CHIEF, COASTAL DEVEL. BRCH.
APPROVAL RECOMMENDED
CHIEF, PLANNING BRANCH

EROSION STUDY
SOUTH SHORE MERRIMACK RIVER
VICINITY OF COAST GUARD STATION
PLUM ISLAND MASS.
LOCATION MAP
SCALE IN FEET
10000 0 10000 20000 30000

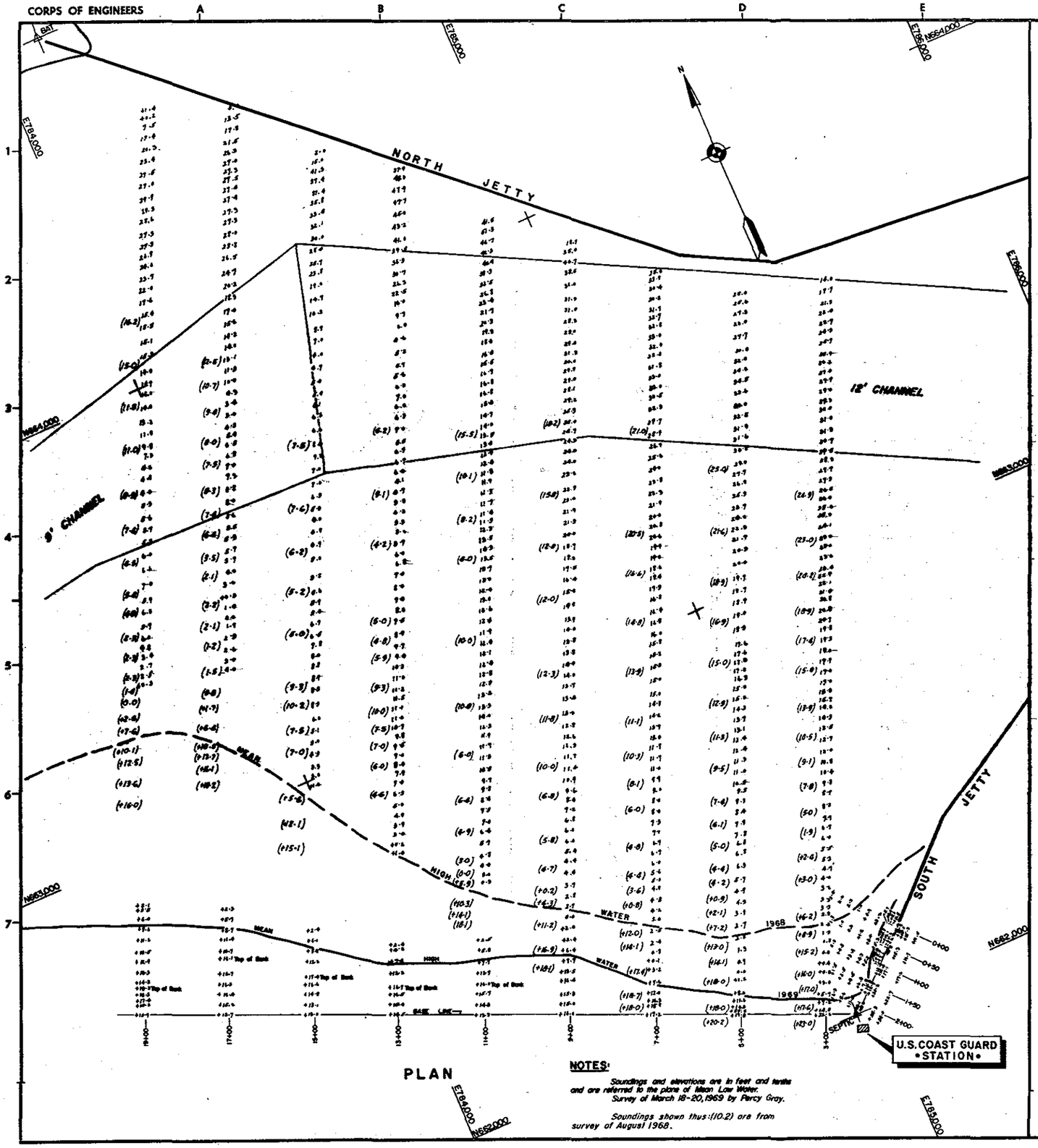
APPROVED: DATE
CHIEF, ENGINEERING DIVISION

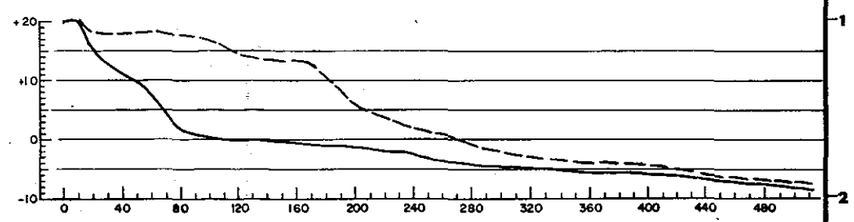
SCALE:
DRAWING NUMBER
SHEET

PLATE NO. 1

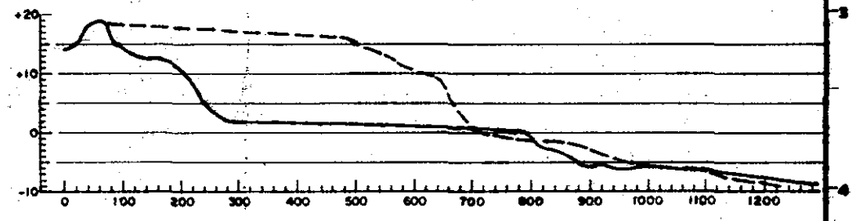
CORPS OF ENGINEERS

U. S. ARMY





STATION 5+00



STATION 19+00

COMPARATIVE PROFILES

LEGEND

1969 Corps of Engrs. ————

1968 " " " — — — —

NOTES:

Soundings and elevations are in feet and tenths and are referred to the plane of Mean Low Water. Survey of March 18-20, 1969 by Percy Gray.

Soundings shown thus:(10.2) are from survey of August 1968.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DIV. ENGR. T.C.B.	BR. ENGR. A.D.C.	CH. BR. C.E.W.

SUBMITTED: PROJECT ENGINEER

CHIEF, COASTAL DEVELOPMENT BRANCH

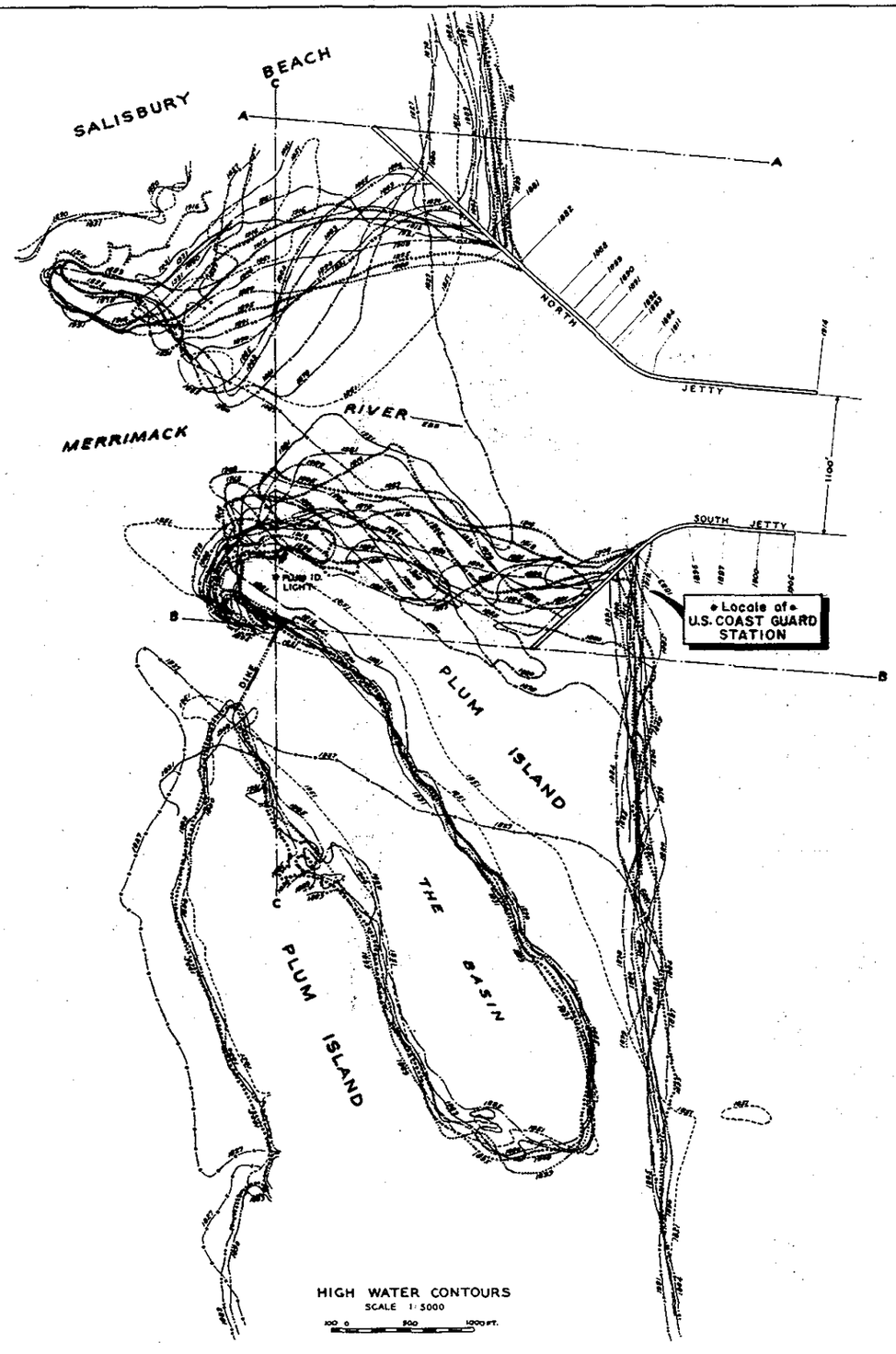
APPROVAL RECOMMENDED: CHIEF, PLANNING BRANCH

APPROVED DATE
CHIEF, ENGINEERING DIVISION

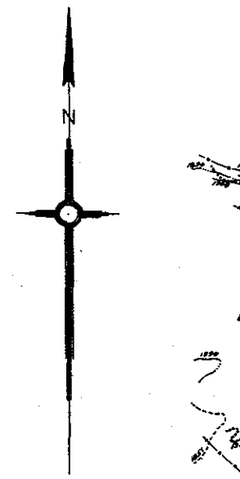
EROSION STUDY
SOUTH SHORE MERRIMACK RIVER
VICINITY OF COAST GUARD STATION
PLUM ISLAND, MASS.
PROFILES
SCALE IN FEET
100 0 100 200 300

SCALE AS SHOWN | SPEC. NO. DACW 33
DRAWING NUMBER
SHEET OF

PLATE NO. 2



HIGH WATER CONTOURS
SCALE 1:5000
100 0 500 1000 FT.

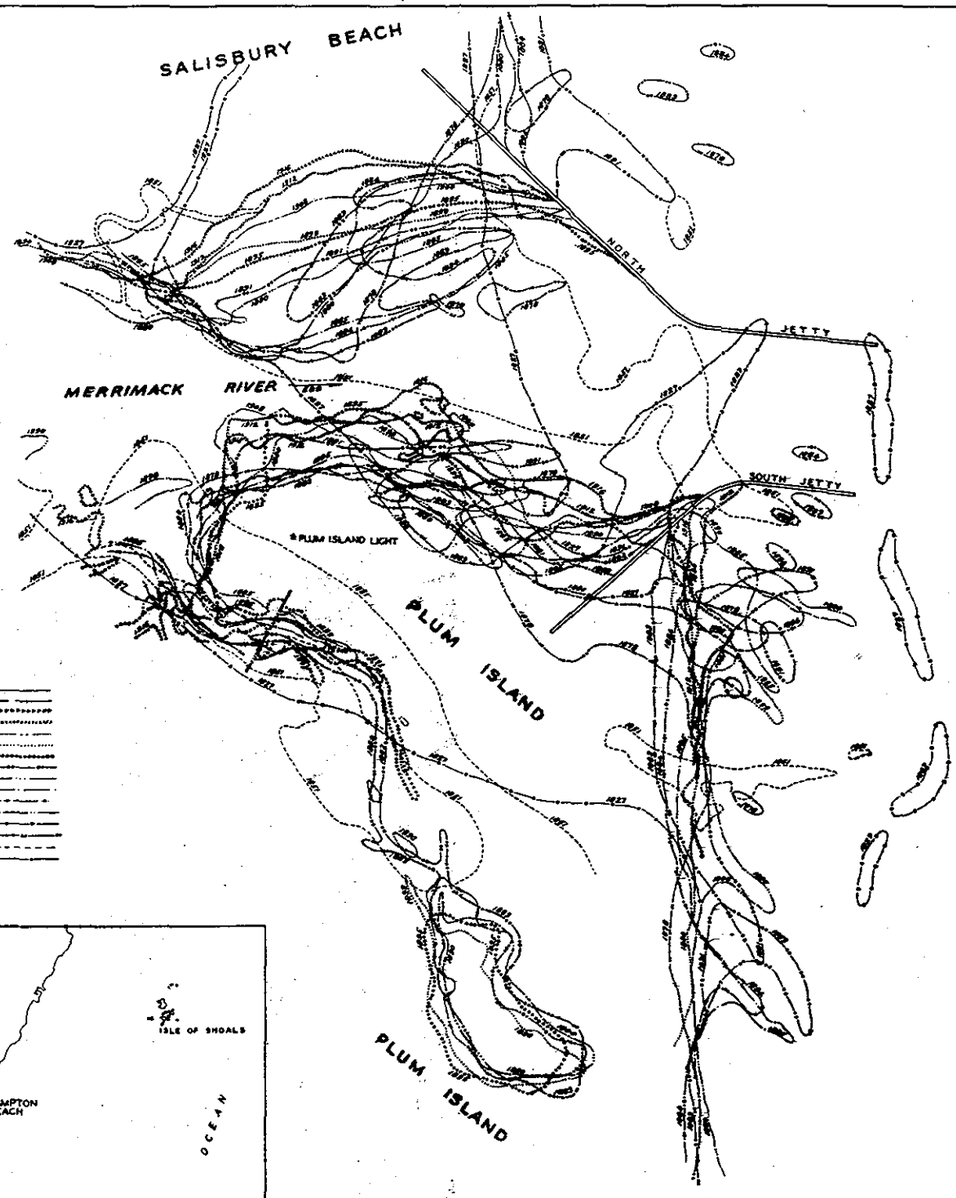


LEGEND

1931
1921
1916
1912
1908
1899
1893
1891
1890
1885
1884
1883
1880
1878
1851
1827

VICINITY MAP
0 1 2 3 4 5 MILES

TAKEN FROM U.S.C.&G.S. CHART NO. 50



LOW WATER CONTOURS
SCALE 1:5000
100 0 500 1000 FT.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY A.D.C.	DE. BY A.D.C.	CK. BY C.E.W.
DIRECTOR		
PROJECT ENGINEER		
CHIEF COASTAL DEVEL. SECT.		
APPROVAL RECOMMENDED: CHIEF, PLANNING BRANCH	APPROVED: CHIEF, ENGINEERING DIVISION	DATE

EROSION STUDY
SOUTH SHORE MERRIMACK RIVER
VICINITY OF COAST GUARD STATION
PLUM ISLAND MASS.
SHORELINE CHANGES

SCALE As shown
DRAWING NUMBER
SHEET

PLATE NO. 3

CORPS OF ENGINEERS

U. S. ARMY

MERRIMACK RIVER

NORTH JETTY

SOUTH JETTY

ATLANTIC OCEAN

PLUM ISLAND

PLUM ISLAND BEACH

AIR FORCE RESERVATION

EXISTING

BACK

SHORELINE

MEAN HIGH WATER --- DEC. 1968

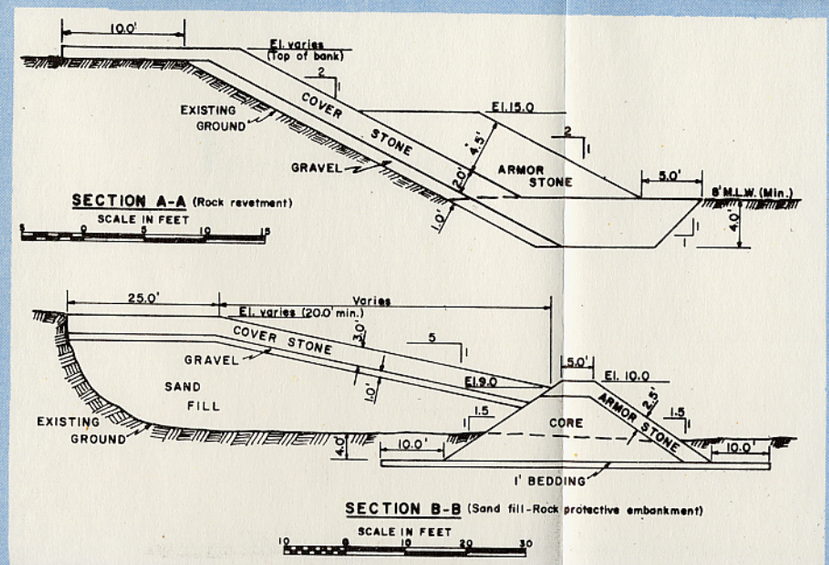
BACK SHORELINE DEC. 1968

CONSIDERED IMPROVEMENT

SOUTH JETTY EXTENSION

UNITED STATES COAST GUARD STA.

THE BASIN



N

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY	TR. BY	CK. BY
T.C.S.	A.D.C.	C.E.W.

SUBMITTED

PROJECT ENGINEER

CHIEF, COASTAL DEVEL. SECT.

APPROVAL RECOMMENDED

CHIEF, PLANNING BRANCH

EROSION STUDY
SOUTH SHORE MERRIMACK RIVER
VICINITY OF COAST GUARD STATION
PLUM ISLAND MASS.
CONSIDERED PLAN OF IMPROVEMENT
SCALE IN FEET
100 0 100 200 300

APPROVED DATE

CHIEF, ENGINEERING DIVISION

SCALE As shown

DRAWING NUMBER

SHEET

PLATE NO. 4